APPRAISAL

The tri-tube freeze-core sampler with the changes described in this paper is an improved device for sampling streambed sediments in the field. The equipment is portable, reliable, versatile, safe, and only moderately expensive to purchase and operate. Capital outlay for the equipment needed to collect 12 samples without refilling $CO_2$ cylinders was $2,000 in early 1979. Cost of materials per sample was $10--the cost of refilling one $CO_2$ cylinder. With a crew of three, up to four samples per hour can be collected, thawed, and stored for analysis.

## Literature Cited


Lotspeich, Frederick B., and Barry H. Reid.
(In press). A tri-tube freeze-core procedure for sampling stream gravels. Prog. Fish Cult.

McNeil, William J., and Warren H. Ahnell.
1960. Measurement of gravel composition of salmon streambeds. Fish. Res. Inst. Circ. 120, 6 p. Univ. Wash., Seattle.

Walkotten, William J.
1976. An improved technique for sampling streambed sediments. USDA For. Serv. Res. Note PNW-281, 11 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

PNW-350 March 1980

# AN IMPROVED TRI-TUBE CRYOGENIC GRAVEL SAMPLER

by

Fred H. Everest, Carl E. McLemore, and John F. Ward[1]

ABSTRACT

The tri-tube cryogenic gravel sampler has been improved, and accessories have been developed that increase its reliability and safety of operation, reduce core extraction time, and allow accurate partitioning of cores into subsamples. The improved tri-tube sampler is one of the most versatile and efficient substrate sampling tools yet developed.

KEYWORDS: Forestry equipment, stream environment, sedimentation.

[1]Fred H. Everest is Research Fisheries Biologist and Carl E. McLemore and John F. Ward are Fisheries Technicians at the Forestry Sciences Laboratory, Corvallis.

## Introduction

Methods for sampling and analyzing the textural composition of gravels used by spawning salmonids have evolved slowly during the past 20 years. The first quantitative samplers to receive general use were metal tubes, open at both ends, that were forced into the substrate. Sedimentary material within the tubes was removed by hand for analysis. A variety of samplers using this principle have been developed, but one described by McNeil and Ahnell (1960) has become widely accepted for sampling streambed sediments.

More recently, scientists began experimenting with cryogenic devices to obtain sediment samples. These devices, generally referred to as "freeze-core" samplers, consist of a hollow probe driven into the streambed and then cooled with a cryogenic medium. After a prescribed time of cooling, the probe and a frozen core of sediment adhering to it are extracted. Liquid nitrogen, liquid oxygen, solidified carbon dioxide ("dry ice") and acetone, dry ice and alcohol, and liquid carbon dioxide ($CO_2$) have been used experimentally as freezing media. Several years of development have produced a reliable sampler (Walkotten 1976) that uses liquid $CO_2$. The freeze-core sampler, like the "McNeil sampler," has become widely accepted.

The accuracy and precision of the freeze-core and McNeil samplers have been compared in laboratory experiments.[2] Samples collected by both devices were found to be representative of a known sediment mixture, but the freeze-core sampler was more accurate (Walkotten 1976). It is also more versatile, functioning under a wider variety of weather and water conditions, but it has a disadvantage. The gravel cores obtained by the single-tube, freeze-core sampler are often too small to allow the core to be stratified into representative subsamples.

Figure 1. Tri-tube sampler in operation.

[2]Koski, K. Victor, and William J. Walkotten, Unpublished data on file at the Forestry Sciences Laboratory, Corvallis, Oreg.

To alleviate problems caused by the size of the cores, the single-tube sampler has been modified by Lotspeich and Reid (in press). The modified freeze-core sampler uses a triangular array of three probes driven into the substrate through a template which keeps the probes in a fixed relation to each other. The "tri-tube" sampler (fig. 1) retains all of the advantages of the single freeze-core sampler, but it extracts larger cores--often more than 20 kilograms--which are probably more representative of substrate composition than cores obtained by either the single freeze-core or McNeil samplers.

We have used the tri-tube freeze-core sampler to investigate the effects of spawning by anadromous salmonids on the spatial and temporal distribution of fine sediments in redds. During the study, we made several improvements in the sampler and developed accessories that have increased reliability and safety of operation, reduced core extraction time, and allowed accurate partitioning of cores into subsamples. The tri-tube sampler described by Lotspeich and Reid (in press), with the addition of improvements described in this paper, is the most versatile and efficient substrate sampling tool yet developed.

# Description of Improvements

## CARBON DIOXIDE DELIVERY SYSTEM

Liquid $CO_2$ for freeze-core sampling is stored and transported in 20-pound (9-kg) capacity aluminum fire extinguisher bottles. The standard valves on the extinguishers are pressure activated and therefore must be tended (hand-squeezed or clamped) while $CO_2$ is metered through manifolds into probes in the substrate. Note that the pressure-activated valves are subject to dangerous accidental discharge of high pressure $CO_2$. We have found that Kidde[3] aluminum fire extinguisher bottles equipped with plastic carrying handles, siphon tubes, and hand-wheel valves (fig. 2) offer two advantages. The hand-wheel valves can be opened and left unattended while $CO_2$ is flowing to the probes, and accidental discharge of $CO_2$ through the hand-wheel valves is nearly impossible.

A second improvement in the $CO_2$ delivery system is a hex nut-gland coupler between the tri-tube manifold and the tank valve (fig. 2). The coupling allows the manifold to be moved quickly from one $CO_2$ bottle to another and prevents twisting of the delivery hoses.

[3]Trade names mentioned are for the convenience of the readers and do not imply endorsement by the U.S. Department of Agriculture.

Figure 2. Carbon dioxide storage tank with hand-wheel valve and three-way delivery manifold with nut-gland attachments.

PROBES

We have used probes constructed of rigid copper, monel, and stainless steel tubing, none of which were fully satisfactory. Although all three metals successfully conduct heat away from the substrate, the thin-walled tubes tend to bend and deform when driven into coarse gravel. We have constructed more rigid probes from 1-inch (2.5-cm) O.D. stainless steel pipe tipped with stainless steel points of the dimensions described by Walkotten (1976). The open end of each probe is fitted with a 3/16-inch (4.8-mm) thick stainless steel collar 2 inches (50.8 mm) long (fig. 3). The collar is scarf-welded around the rim and plug-welded at $180^{\circ}$ intervals on the side. Welded surfaces are subsequently smoothed on a lathe. The collars provide a broad flat surface, which does not bend or deform when the probes are driven, and a shoulder to pull against when the probes are extracted from the substract.

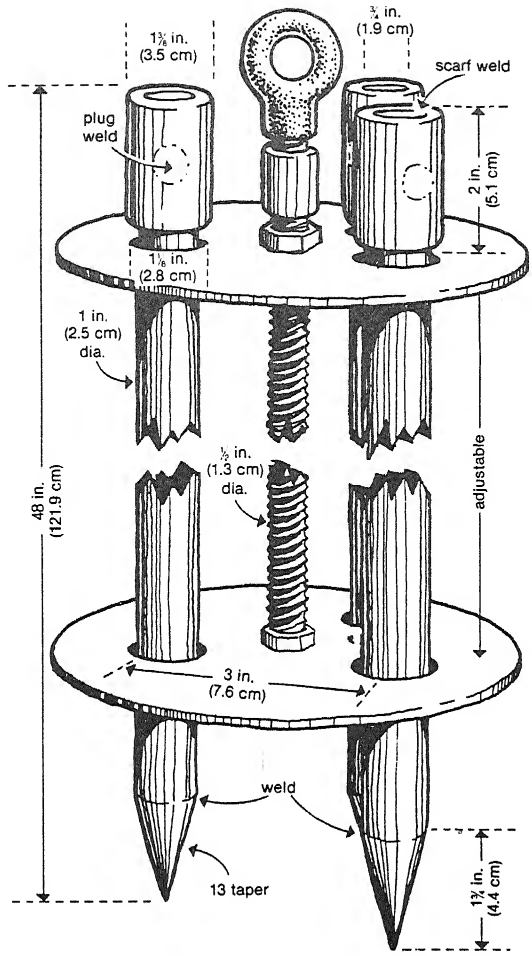



Figure 3. Detail of stainless steel pipe probes and adjustable depth-gage/template.

TEMPLATE

The probe template has been modified to serve three purposes. In addition to holding three probes in a fixed triangular array, our template serves as an adjustable depth-gage for the probes and as the extractor for removing probes with frozen samples from the substrate. The template is constructed from two circular steel plates 1/4 inch (6.4 mm) thick and 5-3/4 inch (14.6 cm) in diameter. Each plate has a triangular array of 1-1/8-inch (28.6-mm) diameter holes spaced 3.5 inches (8.9 cm) on center, and a center hole of 1/2-inch (12.7-mm) diameter. The plates are mounted on a 3-foot (91.4-cm) length of 1/2-inch (12.7-mm) diameter threaded steel rod. The lower plate is fixed on the rod, but the distance between the upper and lower plates can be adjusted by moving hex nuts up or down the threaded rod. This feature allows the template to function as a depth gage and ensures that each probe can only be driven a prespecified distance into the substrate before the probe collar contacts the upper plate of the template.

The upper end of the threaded rod is fitted with a pulling eye that will accept a hook from a small chain hoist (fig. 3). When a sample has been frozen, it can be removed from the substrate in a few seconds with this pulling arrangement. Pulling mechanisms used previously often took several minutes to extract a sample and sometimes permitted surface thawing before extraction.

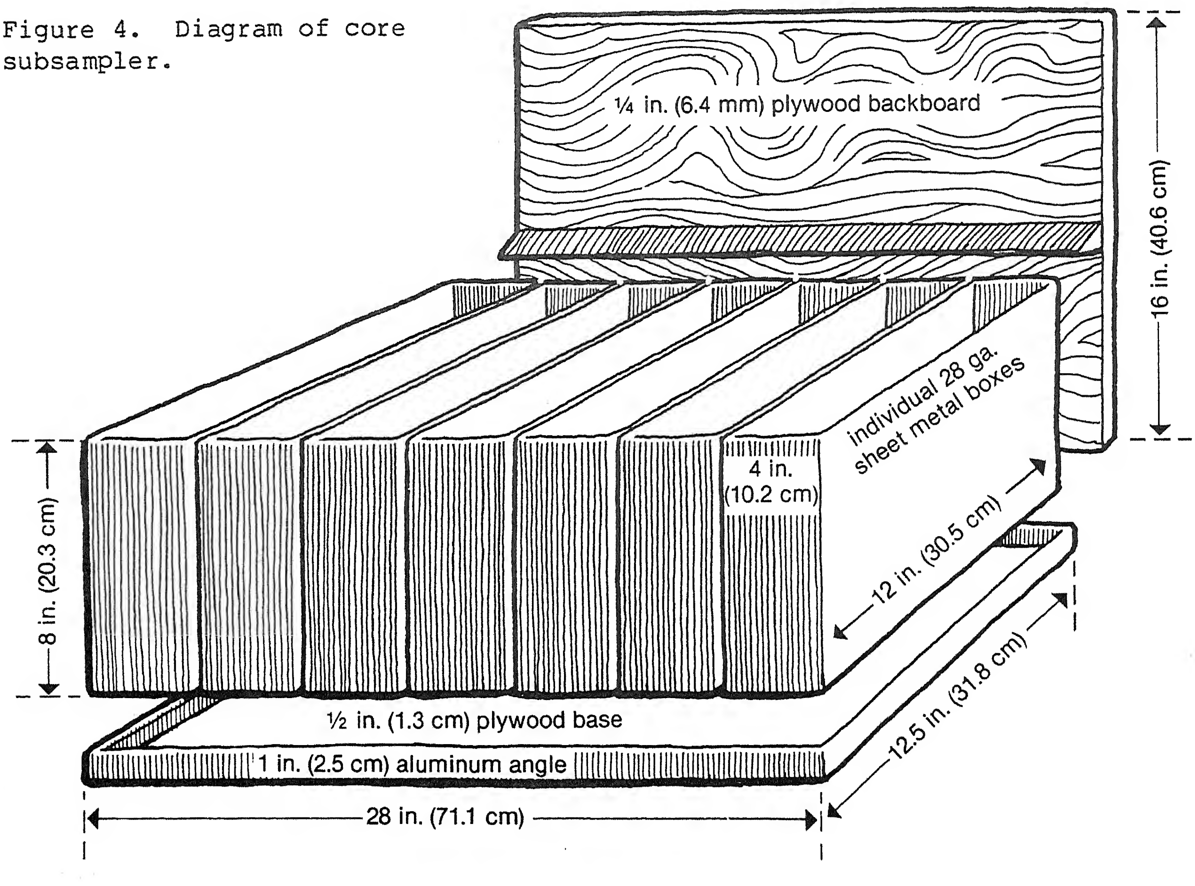
## FLOW SHUNT

We have also developed a flow shunt to improve the size and shape of cores removed from riffles with rapid current and warm water. Swift-flowing water causes incomplete freezing in the upper layers of the core, and some material is often lost during extraction. To eliminate the problem, a shunt constructed from a 2- x 5-ft (61- x 152-cm) piece of 20-gage galvanized sheet metal formed into a teardrop shape (fig. 1) is placed around the probes to divert the current. The shunt functions well in water up to 2 feet (61 cm) deep and at velocities up to 3.5 feet/ second (1.1 m/s); it facilitates consistent freezing throughout the core, especially at the water-substrate interface.

## CORE SUBSAMPLER

A major advantage of the freeze-core sampler is that it provides opportunity for vertical stratification of substrate cores. We have developed a subsampler that consists of a series of open-topped boxes made of 26-gage galvanized sheet metal. The boxes are 12 inches (30.5 cm) long, 8 inches (20.3 cm) high, and either 3 or 4 inches (7.6 or 10.2 cm) wide, depending on the depth stratification desired. The individual boxes are held together on an aluminum-framed plywood tray, 12.5 by 28 inches (31.8 x 71.1 cm) with an elastic strap (fig. 4). A 16 x 28-inch (40.6- x 71.1-cm) plywood backboard is placed upright on the tray along one end of the boxes. A core is laid horizontally on the boxes of the

Figure 4. Diagram of core subsampler.



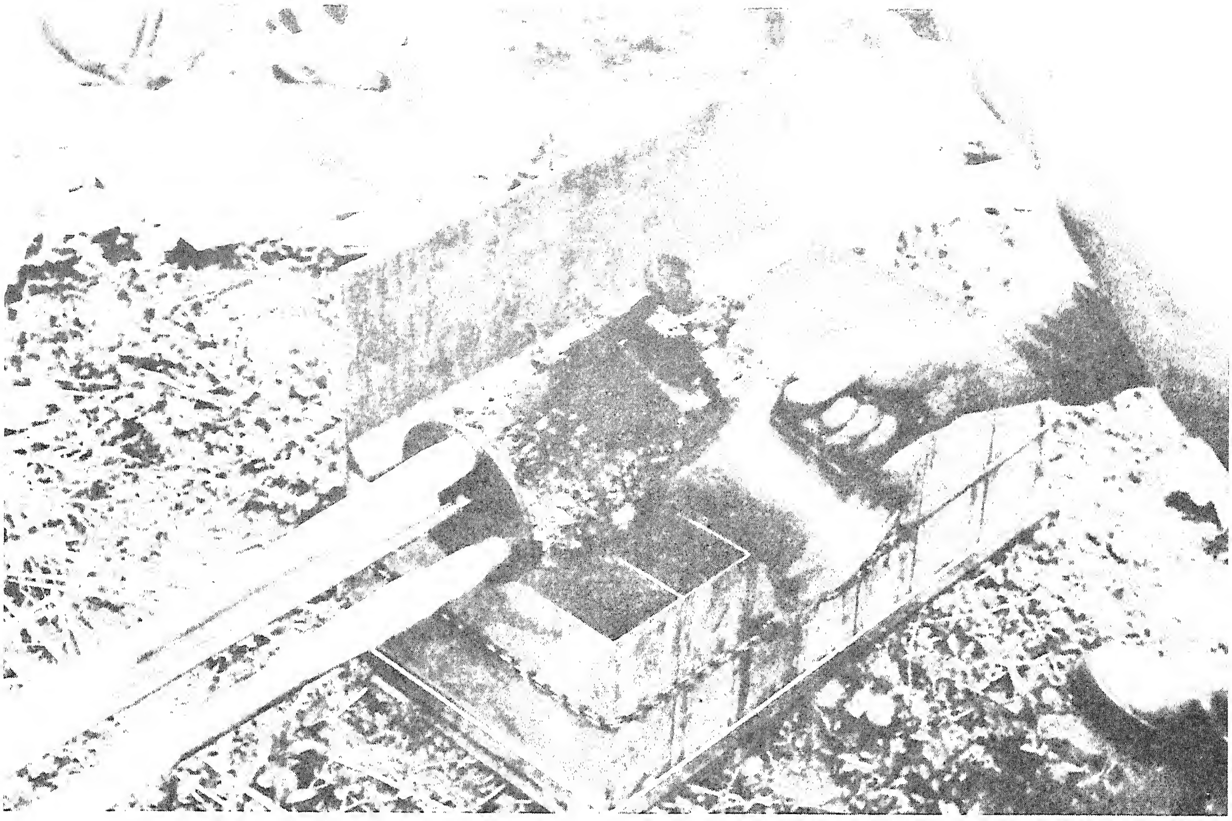


Figure 5. Thawing sample with a blowtorch (note subsampling tray).

subsampler and thawed with a blowtorch fueled with white gasoline (fig. 5). Sediments freed from the core drop directly into the boxes below. Large particles in the sample can be dislodged with a cross-peen or rock hammer and placed in the appropriate boxes.

SAFETY

Liquid $CO_2$ released in the probes changes to a solid and is forcefully ejected as snow-like pellets of dry ice. Because the operator of the equipment must jiggle the manifolds frequently to prevent solid $CO_2$ from accumulating in the probes, precautions must be taken to protect exposed skin and eyes from dry-ice pellets. This is accomplished with a deflector that directs dry-ice pellets away from the operator, safety glasses to protect the eyes, and insulated rubber gloves to protect the hands (see fig. 1). Safety glasses are also used when samples are being thawed, to protect the eyes from flying rock chips caused by differential heating of rock surfaces.